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Cover Photograph: This small woodlot, dissected by an old wide roadbed in Block 7, is dominated by remnant native trees, exotic shrubs, and a mixture of native and exotic vines, and has remained intact since 1994. The woodlot is bordered by the rear facades of commercial buildings on both sides, near the center of downtown Rockingham, NC, but despite its small size and location in the central business district Block 7 remains relatively rich in birds. Photograph © D.B. McNair.

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Breeding Bird Patterns and Species Turnover within the Central Business District of a Town: Results from Rockingham, North Carolina, USA

Douglas B. McNair[1*]

Abstract - Small cities or towns, and in particular central business districts in southeastern North America, are still underrepresented in breeding bird surveys. Using the spot-mapping method, I documented 21 species (17 native suburban adapters, 4 exotic urban invaders) nested within a 25-block study area (42.4 ha) of downtown Rockingham (population ~9,000) in south-central North Carolina in 1994. The 156 breeding pairs had a density of 147.1 territories (T)/40 ha (native: 90.5 T/40 ha, exotics: 56.6 T/40 ha). The 6 most abundant species were 3 exotics (European Starling: 20.8 T/40 ha; House Sparrow: 18.9 T/40 ha; House Finch: 12.3 T/40 ha) and 3 natives (Common Grackle: 17 T/40 ha; Mourning Dove: 14.6 T/40 ha; American Robin: 12.7 T/40 ha). I documented 433 nests and confirmed breeding records, 324 (75%) of which were open-cup nests. Each species nested entirely (or almost entirely) in vegetation or on or within buildings and other anthropogenic structures. Only House Finches, before an outbreak of mycoplasmal conjunctivitis reached Rockingham, nested at almost an equal number of vegetative and building sites. Median species richness and number of nest records were significantly greater in vegetation than at buildings; only 4 of 25 blocks (16%) had a higher proportion of their nest records at buildings. Supplemental surveys conducted 18–23 years later (2012, 2016–2017) that focused on species turnover documented the loss of 2 of the 3 most numerous native species (Common Grackle, American Robin), even though habitat remained largely unchanged.

Introduction

Urbanization connotes changes in landscape (or environment) caused by urban development (Marzluff 2001, Marzluff et al. 2001). Biotic homogenization is characteristic of urban landscapes, where resident habitat generalist avian species thrive and Neotropical and Palearctic migrants sharply drop in richness (Aldrich and Coffin 1980, Aronson et al. 2014, Beninde et al. 2015, Blair 2004, Chace and Walsh 2006, Clucas and Marzluff 2015, Emlen 1974, Kelcey and Rheinwald 2005, La Sorte and McKinney 2007, Leston and Rodewald 2006). Most avian studies of biotic homogenization in urban landscapes of North America have been conducted in residential areas, parks, riparian corridors, and forest fragments of suburbia (Aronson et al. 2014, Belaire et al. 2015, Beninde et al. 2015, Chace and Walsh 2006, Clucas and Marzluff 2015, Duren et al. 2017, Leston and Rodewald 2006, Marzluff and Rodewald 2008, Schneider and Miller 2014), including locations in the southeastern United States (Aldrich and Coffin 1980, Rohwer and Woolfenden 1969, Thorington and Brand 2014, Woolfenden and Rohwer 1969). For example, Woolfenden and Rohwer (1969) emphasized relationships between the density of breeding pairs of avian species and a variety of landscape variables within the urbanized matrix of Tampa, Florida. More recently, in Winston-Salem, North Carolina, breeding bird censuses (hereafter, BBCs) using spot-mapping of territories over 2 years documented 60 breeding species in a large park (77-ha) surrounded by suburban residential housing (Thorington and Brand 2014). In southeastern North America, no BBCs, other than in large urban areas, have been conducted in a town and none in a central business district. The closest locations known to the author have been towns in eastern Kansas (Baldwin City) and northern Ohio (Carey), where both residential and commercial areas were censused (Cink

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1983, Claugus 1983). Overseas, in the Czech Republic (Kučera et al. 2015) and in Germany (Nicolai and Wadewitz 2003), a few recent assessments of avian communities that included central business districts have been published for towns similar in size or somewhat larger compared to Rockingham, Richmond County, North Carolina.

Rockingham has long been a bird-friendly town, with posted signs announcing it was designated a bird sanctuary in the early 1950s (Barber 1952). Rockingham, unlike most large urban areas of North Carolina, but like most towns and small cities in the Pee Dee region of the Carolinas, has a stagnant economy, is not expanding geographically, and has not increased in population for over 35 years (Hutchinson et al. n.d.; US Census Bureau 2020). The landscape of Rockingham's central business district and outlying urban areas has remained largely unchanged, unlike larger urban centers with dynamic economies and expanding populations where most avian studies on urbanization effects have been conducted (e.g., Seattle, Washington; Clucas and Marzluff 2015). Thus, birds in Rockingham have had low urbanization pressure, but they have faced pressure from other factors. For example, the spread of mycoplasmal conjunctivitis in *Haemorhous mexicanus* (P.L. Statius Müller) (House Finch) populations, an urban invader, began in eastern North America in 1994 (Badyaev et al. 2012). Furthermore, several species of suburban adapters that may breed in towns have had regional range expansions (McNair 2019) or contractions (McNair 2015) that have included Rockingham over the past decade. The scarcity of studies from towns in rural North America, stagnant development, and dynamics of other factors create a need for a better understanding of avian species relationships in smaller urban landscapes such as Rockingham. The main objectives of this study were to (1) examine patterns of functional guilds, bird species richness, and nest densities in relationship to built-up land and vegetation and (2) discuss species turnover 2 decades after first sampling at Rockingham in 1994.

Methods

Study Area Description

Rockingham, North Carolina, the county seat of Richmond County, is a micropolitan statistical area. Rockingham was founded in 1774 at Cole's Hill (Hutchinson 1998), a bluff rising between Hitchcock and Falling Creeks, along the contact zone (Fall Line) where the Piedmont meets the Sandhills, a subregion of the Coastal Plain. The study area is centered on the ancient location of Cole's Hill, which comprises the central business district of Rockingham (although most commercial development in the micropolitan statistical area now occurs along US BUS 74 between Rockingham and Hamlet, 8 km east-southeast). The estimated population of Rockingham, the county's most populous community, was 8994 in 2018, a decline of 4.3% from its population of 9399 in 1990 (US Census Bureau 2020).

The study area (42.4 ha; Fig. 1) on Cole's Hill in the central business district of Rockingham (henceforth called downtown Rockingham: Latitude 34.939528 N, Longitude 79.761236 W; 87 m asl) excludes town blocks of adjacent residential areas. The study area, on flat to moderately steep terrain, is bounded on the west and south sides by the intersection of US 220 and US BUS 74. These 2 major highways connect to town streets that define the northern and eastern boundaries of the study area (Fig. 1). The southeastern boundary of the study area that encloses business district parcels includes a ruderal habitat patch dominated by *Pueraria* (Kudzu). The closest points along Hitchcock and Falling Creeks are located 60 m and 40 m, respectively, outside the northwestern and southeastern boundaries of the study area.

The study area does not contain commercial buildings taller than 3 stories, riparian or other aquatic habitats, forests, woodlands, farmland, parks, cemeteries, allotment gardens, or industrial areas. Downtown Rockingham contains a mixture of cropped (maintained) remnant native vegetation and exotic vascular plants. Plantings on properties in the central business district usually adhered to recommendations of regulations by the City of Rockingham (2020). The tallest tree within the study area was 30 m high.

I digitized individual block size within the 25-block study area from recent (2016) high resolution aerial imagery, which I analyzed in ESRI's ArcGIS 10.4 software. The mean and median block sizes were 1.70 ha (± 0.20 SE) and 1.46 ha (interquartile range: 1.20–2.07 ha), respectively (min–max range: 0.18–4.12 ha). I used street centerlines to demarcate the boundaries between blocks except along the eastern boundary where vegetation formed the outer boundary of 3 blocks (nos. 4–5, 16).

Land Cover Data

The City of Rockingham (J.E. Armstrong, past Planning Director, City of Rockingham, NC, pers. comm.), in 1994, provided the area of buildings within each block, which totaled 6.59 ha (15.5% of the total study area); this amount does not include streets, pavements, and

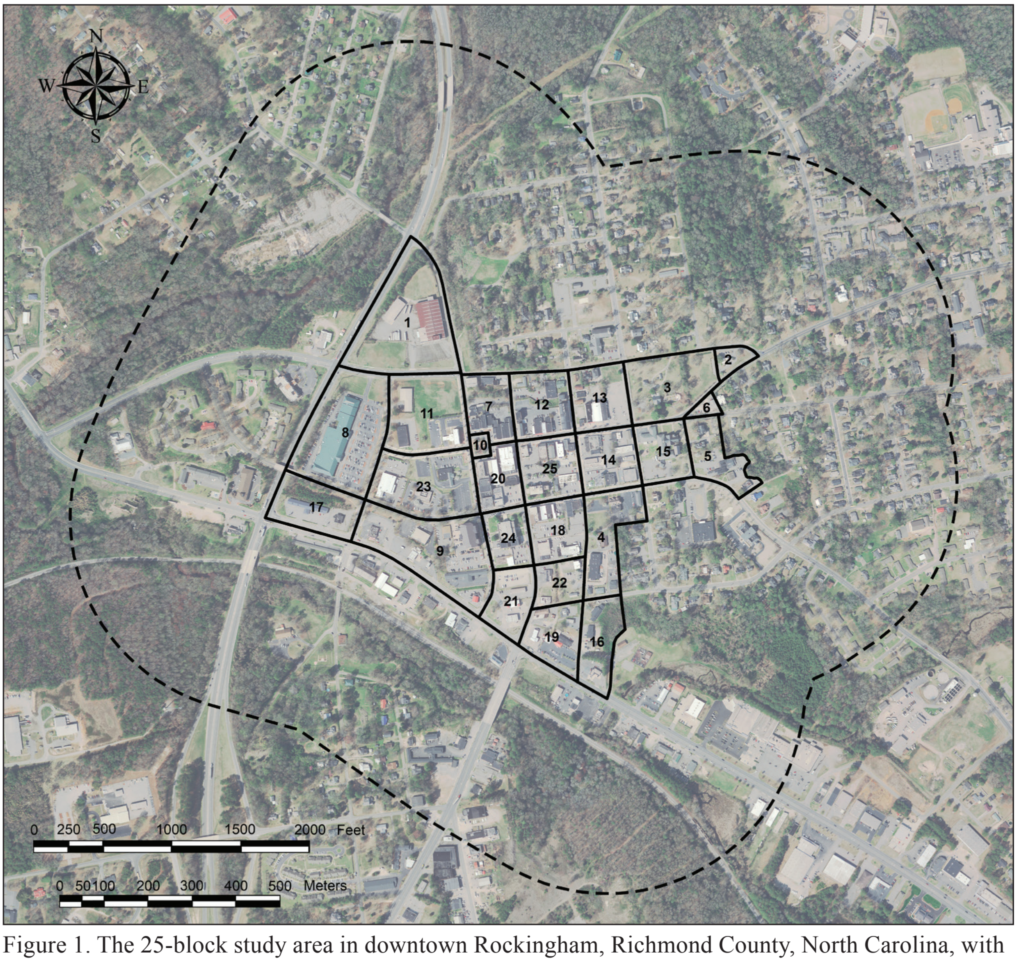

Figure 1. The 25-block study area in downtown Rockingham, Richmond County, North Carolina, with each block represented by a number, largely consists of buildings and other sealed surfaces, with smaller areas of a mixture of native and exotic vegetation, including lawns. The 0.4-km perimeter beyond the study area boundary is designated by a black dashed line. The source of the image is from the North Carolina Orthoimagery Program (date of imagery 8 March 2015) and is being used with permission.

other impervious surfaces on the ground. The mean and median areas of buildings within blocks were 0.26 ha (± 0.036 SE) and 0.24 ha (interquartile range: 0.12–0.37 ha), respectively (min–max range: 0.02–0.66 ha).

I developed a vegetation index for the diverse mixture of remnant native vegetation and landscaped plantings by overlaying an acetate grid of mylar squares on magnified aerial photographs of each of the 25 blocks at a scale of 1:840 (2.54 cm:21.336 m; original measurements: 1 in:70 ft). This vegetation index relied upon estimation of the spatial coverage of vascular plants within each block. I excluded measurements of any exaggerated images of vascular plants. If vegetation filled at least 50% of a mylar square, I scored it as 1 square. This index excluded plants less than 1 m tall and ground vegetation, including lawns, where birds did not nest.

I reassessed the study area 18 to 23 years later (2012, 2016–2017) for any changes in habitat and landscape characteristics (including buildings and paved surfaces) that may have occurred since 1994. I examined photographs and field notes I took in 1994 to compare with field inspections during the 3 later years. I also compared individual blocks from past (1993) and recent (2013, 2017) aerial imagery for all 25 blocks and used the vegetation index as I did in 1994 to quantify vegetative changes.

Avian Surveys

Species nomenclature for scientific names, authorities, and common names follows Chesser et al. (2019) and ITIS (2020). I conducted avian surveys on 94 days from 27 March to 18 September 1994; field effort was concentrated from April through July (236.75 of 252.25 h; 94%). Less search effort occurred before noon (79.5 h; 31.5% of total) than afterward. The BBC uses the spot- or territory mapping method to estimate densities (Aldrich and Coffin 1980, Gardali and Lowe 2006, Leston and Rodewald 2006, Thorington and Brand 2014). Following this protocol during the peak breeding period (April to early June) for species that maintained exclusive multi-purpose territories, I rounded the number of territories to the nearest half territory. There were 8 species that may not maintain exclusive multi-purpose territories but may only defend nesting-station territories as isolated pairs (although several species may nest semi-colonially): *Columba livia* var. *domestica* J.F. Gmelin (Feral Pigeon), *Zenaida macroura* (L.) (Mourning Dove), *Chaetura pelagica* (L.) (Chimney Swift), *Cyanocitta cristata* (L.) (Blue Jay), *Sturnus vulgaris* (L.) (European Starling), *Passer domesticus* (L.) (House Sparrow), House Finch, and *Quiscalus quiscula* (L.) (Common Grackle). In addition to spot-mapping, I used the location of active nests or confirmed breeding attempts without direct evidence but based on observations of behavior (e.g., adults of cavity-nesting species repeatedly entering a cavity with food) to confirm the number of territories for these 8 species. The number of pairs for Feral Pigeons was considered to be half of their individual numbers recorded in 1 count (Luniak 1994). For Chimney Swifts, the number of chimneys that were regularly used constituted the number of breeding pairs since only 1 pair nests per chimney (Steeves et al. 2014). I standardized breeding densities within the study area by calculating the number of territories per 40 ha; this calculation included species with less than 3.0 territories.

I also conducted intensive nest searches to complement use of the spot-mapping method to delineate territories. Nest records had the advantage that they could be consigned to an individual block and its specific vegetative and anthropogenic characteristics unlike many territories, which encompassed more than 1 block. Most effort was devoted to obtaining information on open-cup breeding species (which included 1 urban invader, the House Finch) rather than cavity-nesting species. The latter's nests were generally inaccessible, although their breeding activity was closely monitored. The 12 most numerous species (see Results) were multiple-brooded, except for the Common Grackle, which is usually single-brooded (Peer and Bollinger 1997).

I supplemented 1994 data by obtaining additional information in 2012 and 2016–2017. I conducted these supplemental surveys on 24 days from 7 April to 2 June for a total of 35.5 h. Search effort before (17 h; 48%) and after noon (18.5 h; 52%) was approximately equal. The focus was on documentation of species turnover (presence or absence), the number of territories of species that were scarce in 1994, and the number of territories of new species discovered during the later period. Otherwise, I did not map territories or attempt to find nests of the more numerous species. These efforts allowed me to document any species turnover that occurred between 1994 and the 3 later years.

During avian surveys from March to September 1994, I obtained weather data at Hamlet, North Carolina (Latitude 34.8872 N, Longitude 79.6922 W, 107 m asl) because comparable weather data were not available from Rockingham (NRCC 2017). In comparison to Normals period (1981–2010) data during these 7 months, temperature and precipitation in 1994 were slightly cooler and wetter than average. The exception was rainfall of 38.05 cm in July 1994, the highest rainfall during July over this 30-year period.

Data Analysis

Functional guilds. Breeding birds in the central business district of Rockingham can be loosely categorized into 2 functional guilds based on their differing responses to urbanization—urban invaders and suburban adapters (Marzluff and Rodewald 2008; adopted and developed from Blair 1996). Urban invaders (e.g., European Starling) are rare in natural areas and abundant and fecund in urban areas. Suburban adapters (e.g., American Robin L. [*Turdus migratorius*]) are typically adapted to diverse, young, edge, and disturbed habitats (Marzluff and Rodewald 2008). These species would include the Chimney Swift, which readily occupies buildings in suburban and urban environments.

Biodiversity measures. I calculated species richness (number of different species present), which is the most studied attribute of urban communities (Marzluff and Rodewald 2008), densities of breeding birds, and number of nests and confirmed breeding attempts (henceforth called nest records) for the entire 25-block study area and, where applicable, for each individual block in downtown Rockingham in 1994. The number and location of nest records were used to measure each species distribution in the study area. I examined scatterplots and conducted non-parametric Spearman's correlation tests to assess monotonic links between these 3 biodiversity measures (species richness, breeding density, number of nest records). Species richness among all blocks was strongly correlated with the total number of nest records, the number of nest records in vegetation, and the number of nest records at buildings (r_S = 0.87, 0.83, and 0.90, respectively; all $P < 0.001$). Furthermore, the breeding bird densities of all species was strongly correlated with the number of nest records (r_S = 0.83, $P < 0.001$). Thus, use of the number of nest records in subsequent analyses was justified.

Effects of buildings and vegetation. Landscape regulations of the City of Rockingham (2020) stipulate that 5 blocks (nos. 1, 2, 8, 16, 17; see Fig. 1) and a portion of properties within 3 other blocks (nos. 9, 11, 21) should consist of a minimum of 12% landscaped areas, which includes lawns. The remaining 17 blocks are exempted from this regulation, and their landscaped areas can be less than 12%. Excluding lawns, the median difference in landscaped areas between these 2 groups (≥12%, <12%), using the vegetation index, was not significantly different (Mann–Whitney U = 37, 2-tailed test, P = 0.08). Therefore, I made no distinction in the proportion of spatial coverage of vascular plants in landscaped areas among the 25 blocks.

I used 2-tailed non-parametric Wilcoxon signed-rank tests to examine median differences between non-independent matched-pair observations (buildings, vegetation) from each block, across all 25 blocks, for species richness and the number of nest records (I omitted Block 1 for nest records because search effort in vegetation was inadequate). I examined scatterplots and conducted non-parametric Spearman's correlation tests to assess whether building area and the vegetation index were monotonically linked to species richness or the number of nest records across all blocks (omitting Block 1 for testing with the vegetation index) for each of the 10 most abundant species.

I also conducted a first-order partial correlation analysis to examine the effects of building area and the vegetation index on species richness and the number of nest records for all species across all blocks, after adjustment for the effect of block size. I converted values using a log10 (n + 1) transformation for 3 of 4 variables (species richness, nest records, block size) in the building analysis and 2 of 4 variables (vegetation index, block size) in the vegetation analysis so the data became normally distributed or more closely approximated a normal distribution; data transformation eliminated outlier values and ensured homogeneity of variances. All analyses were performed with statistical software available from McDonald (2014) and Real Statistics Using Excel (2019).

Results

Avian Survey

Species richness. Twenty-one avian species (16 passerines) nested within the study area of downtown Rockingham in 1994 (Table 1), including 13 open-cup species (10 residents, 3 Neotropical migrants) and 8 cavity species (6 residents, 2 Neotropical migrants). Seventeen species were native suburban adapters, whereas 4 species were exotic urban invaders. An additional 30 avian species visited the study area during the breeding season in 1994 but did not breed (Appendix 1). Twenty-one of these 30 visitors plus an additional 20 species bred within 0.4 km of the perimeter of the study area in 1994 (Appendix 1). These species included *Molothrus ater* (Boddaert) (Brown-headed Cowbird), which was not detected within the study area after 27 March.

Breeding densities. Breeding bird density for all 21 species during the peak season (April–early June) was 156 territories (Table 1), a density of 147.1 territories (T)/40 ha (native: 90.5 T/40 ha, 61.5%; exotics: 56.6 T/40 ha, 38.5%). Resident species accounted for 146 territories (93.6%; 137.7 T/40 ha), whereas the 5 Neotropical migrants accounted for 10 territories (6.4%; 9.4 T/40 ha), including 6 territories of *Dumetella carolinensis* (L.) (Gray Catbird). The 6 most abundant species were 3 exotics (European Starling: 20.8 T/40 ha; House Sparrow: 18.9 T/40 ha; House Finch: 12.3 T/40 ha), which included 2 cavity species, and 3 natives (Common Grackle: 17 T/40 ha; Mourning Dove: 14.6 T/40 ha; American Robin: 12.7 T/40 ha). The Common Grackles nested as isolated pairs and semi-colonially (in Block 25). Nine of the 21 breeding species (43%) each had only a single territory.

Nest records. I found 433 nest records in 1994 (Table 1), 324 (75%) of which were open-cup nests. These findings included nest records for all 7 native species present on single territories in 1994. Only *Thryothorus ludovicianus* (Latham) (Carolina Wren) nest records in 1994 were proportionally under-recorded compared to their number of breeding territories (Table 1).

Distribution. The most abundant species were generally the most widely distributed species within the 25-block study area, based on the total number of nest records of each species among all blocks (Table 1; Fig. 2A: $r_S = 0.97$, $P < 0.001$). Sixteen species breeding in vegetative nest sites separated themselves into 3 groups: 8 sparsely distributed species (including European Starling), 5 moderately distributed species (Gray Catbird, *Toxostoma rufum* [L.] [Brown Thrasher], House Finch, Common Grackle, *Cardinalis cardinalis* [L.] [Northern Cardinal]), and 3 widely distributed species (Mourning Dove, American Robin, *Mimus polyglottos* [L.] [Northern Mockingbird]; Fig. 2B: $r_S = 0.99$, $P < 0.001$). Nine species breeding at buildings separated themselves into 3 groups: 4 sparsely distributed species (including Mourning Dove and American Robin), 2 moderately distributed species (Feral Pigeon, Carolina Wren), and 3 widely distributed species (European Starling, House Sparrow,

Table 1. Number of territories, territories per 40 ha, nest records, and city blocks with nests for 21 avian species that bred within the 25-block study area in downtown Rockingham, North Carolina, in 1994.

Scientific name (Common name)	Number			
	Open-cup and open-air[1] breeding species			
	Territories	Territories/40 ha	Nest records	City blocks with nests
Zenaida macroura (L.) (Mourning Dove)	15.5	14.6	56	19
Charadrius vociferus L. (Killdeer)	1	0.9	2	1
Lanius ludovicianus L. (Loggerhead Shrike)	1	0.9	1	1
Cyanocitta cristata (L.) (Blue Jay)	1	0.9	1	1
Turdus migratorius L. (American Robin)	13.5	12.7	63	22
Dumetella carolinensis (L.) (Gray Catbird)	6	5.7	31	11
Toxostoma rufum (L.) (Brown Thrasher)	9	8.5	26	12
Mimus polyglottos (L.) (Northern Mockingbird)	11	10.4	51	21
Haemorhous mexicanus (P.L. Statius Müller) (House Finch)	13	12.3	40	16
Icterus spurius (L.) (Orchard Oriole)	1	0.9	1	1
Quiscalus quiscula (L.) (Common Grackle)	18	17.0	25	10
Cardinalis cardinalis (L.) (Northern Cardinal)	6	5.7	26	14
Passerina caerulea (L.) (Blue Grosbeak)	1	0.9	1	1
Subtotal	97	91.5	324	na[2]

and House Finch; Fig. 2C: $r_S = 0.92$, $P < 0.001$). The distributions of European Starlings and House Sparrows at buildings were truncated at 12 blocks, despite their greater abundances in comparison to the House Finch. European Starlings and House Sparrows were less widely distributed compared to the 4 most widely distributed open-cup nesting species (including the House Finch, which nested in a total of 16 blocks, vegetative and building sites combined).

Effects of Buildings and Vegetation

Median species richness and the number of nest records of matched-pair observations at blocks, across all 25 blocks, were significantly greater in vegetation (species richness = 6, interquartile range = 4–7, min–max = 0–9; number of nest records = 13, interquartile range = 5–17, min–max = 0–33) than at buildings (species richness = 2, interquartile range = 1–3,

Table 1. Continued.

Scientific name (Common name)	Number			
	Cavity and crevice breeding species[3]			
	Territories	Territories/40 ha	Nest records	City blocks with nests
Columba livia var. *domestica* J.F. Gmelin (Feral Pigeon)	5	4.7	12	7
Chaetura pelagica (L.) (Chimney Swift)	1	0.9	1	1
Melanerpes carolinus (L.) (Red-bellied Woodpecker)	1	0.9	1	1
Myiarchus crinitus (L.) (Great Crested Flycatcher)	1	0.9	1	1
Sitta pusilla Latham (Brown-headed Nuthatch)	1	0.9	1	1
Thryothorus ludovicianus (Latham) (Carolina Wren)	8	7.6	7	6
Sturnus vulgaris L. (European Starling)	22	20.8	47	14
Passer domesticus (L.) (House Sparrow)	20	18.9	39	12
Subtotal	59	55.7	109	na[2]
TOTAL	156	147.1	433	na[2]

[1] The Mourning Dove builds a simple platform nest; the Killdeer laid its eggs in a scrape on a rooftop.
[2] na = not applicable.
[3] The Feral Pigeon builds a simple platform nest on ledges located in the interior of buildings; the Chimney Swift builds stick nests glued together by saliva inside open chimneys or in interior walls of abandoned buildings; the Carolina Wren usually builds domed nests with side entrances in crannies or other secluded places; the House Sparrow builds open-cup to globular-shaped nests in crevices in a variety of anthropogenic structures.

min–max = 0–7; number of nest records = 3, interquartile range = 1–10, min–max = 0–15; species richness: Wilcoxon signed-rank test: $Z = 3.86$, $n = 25$, $P < 0.001$; number of nest records: Wilcoxon signed-rank test: $Z = 2.94$, $n = 24$, $P = 0.003$). Four of 24 blocks (17%) had a higher proportion of their nest records at buildings, 1 block had an equal proportion (4%), and 19 of 24 blocks (79%) had a higher proportion of their nest records in vegetation (Fig. 3).

Building area and the vegetation index were positively associated with the number of nest records at buildings and in vegetation, respectively, for each of the 10 most abundant species. These trends were significant at buildings for 2 urban invaders (European Starling, House Sparrow; r_S range = 0.54–0.61, $n = 25$, P range = 0.001–0.006) and 4 suburban adapters (Mourning Dove, Gray Catbird, Brown Thrasher, Northern Cardinal;

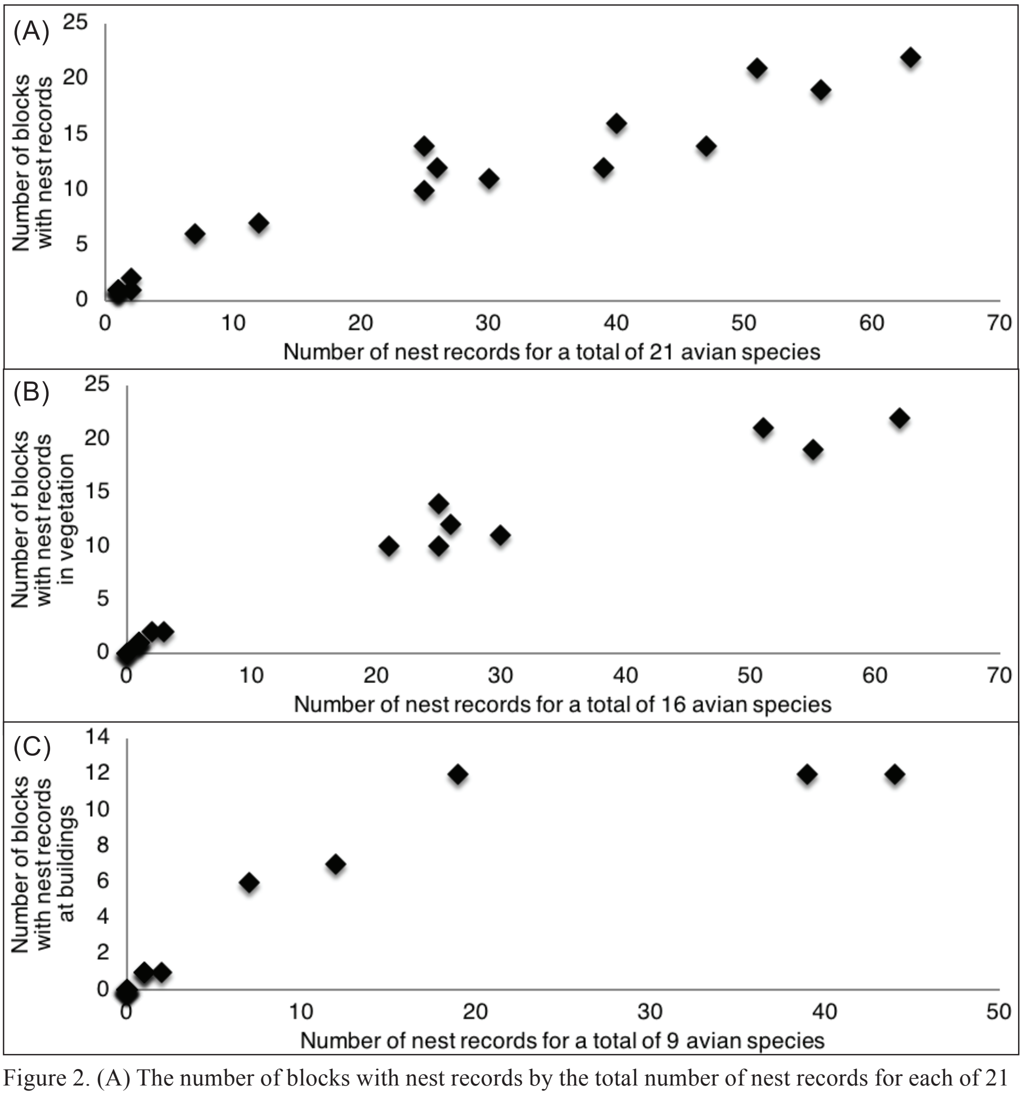

Figure 2. (A) The number of blocks with nest records by the total number of nest records for each of 21 avian species; (B) the number of blocks with nest records by the number of nest records in vegetation for each of 16 avian species; and (C) the number of blocks with nest records by the number of nest records at buildings for each of 9 avian species that bred in downtown Rockingham, North Carolina, in 1994.

r_S range = 0.43–0.59, n = 24, P range = 0.002–0.03). The weakest associations were for the House Finch, at buildings (r_S = 0.09, n = 25, P = 0.66) and in vegetation (r_S = 0.001, n = 24, P = 0.997).

Building area was positively associated with species richness and the number of nest records at buildings for all species but the trends were not significant after adjustment for the effect of block size (species richness: r_p = 0.32, n = 25, P = 0.12; nest records: r_p = 0.36, n = 25, P = 0.09; first-order partial correlation tests). However, examination of scatterplots revealed that species richness was disproportionately high in Block 12 and disproportionately low in Blocks 8 and 18, and there was a disproportionately high number of nest records in Block 19. In contrast, the vegetation index was significantly associated with species richness and the number of nest records in vegetation for all species, after adjustment for the effect of block size (species richness: r_p = 0.50, n = 24, P = 0.02; nest records: r_p = 0.49, n = 24, P = 0.02). Nonetheless, examination of scatterplots revealed a disproportionately high number of nest records in Block 25 (where a Common Grackle semi-colony was located) and a disproportionately low number in Block 16 (where the Kudzu patch was located).

Land Cover Change

In 1994, the study area contained bird feeders at 4 locations in 4 blocks, bird baths at 3 locations in 3 blocks, and 1 nest box in 1 block. Isolated snags were present in ~5 blocks.

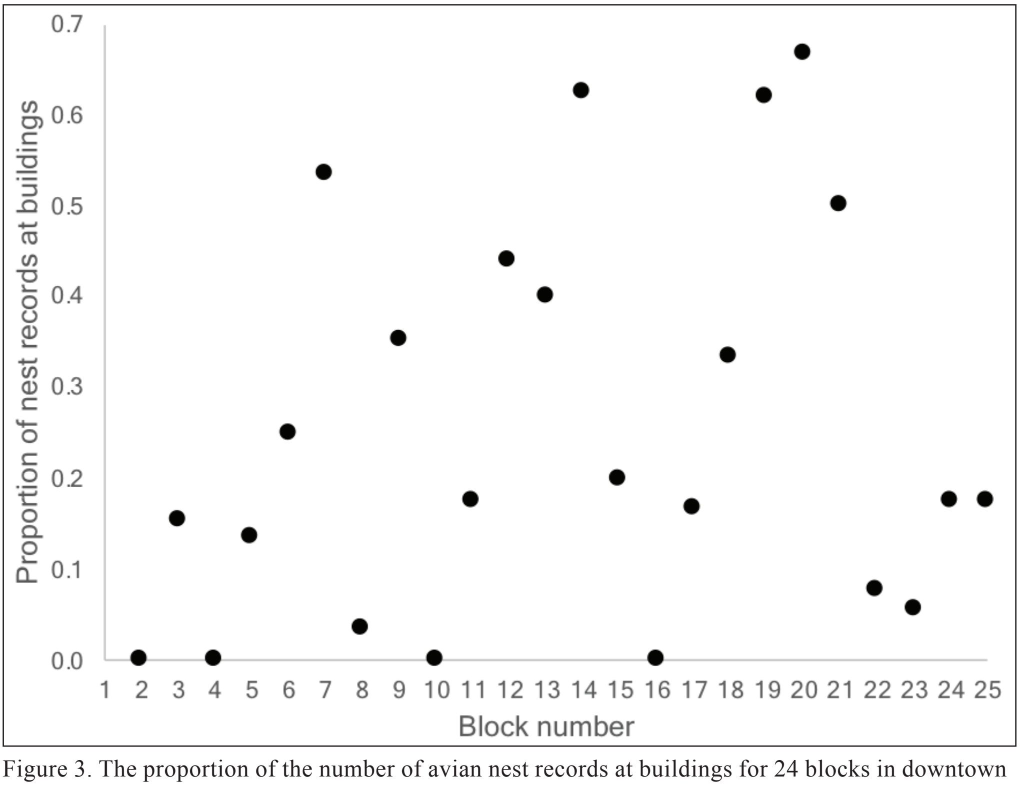

Figure 3. The proportion of the number of avian nest records at buildings for 24 blocks in downtown Rockingham, North Carolina (Block 1 is omitted because search effort in vegetation was inadequate); each block is denoted by a number from Figure 1. An equal proportion of nest records at buildings and vegetation is indicated by a value of 0.5, a value >0.5 indicates a greater proportion at buildings, and a value <0.5 indicates a greater proportion in vegetation.

By 2012, 1 bird bath was still present in the study area, but bird feeders and nest boxes were absent, and all isolated snags had been removed.

The sum total loss of vegetation in the later period compared to 1994, as measured by the vegetation index, was 5.4%; thus, 94.6% of spatial coverage of vascular plants from 1994 was still present. Habitat and landscape characteristics in the 3 later years remained unchanged since 1994 in 19 of 25 blocks (76%). Five of the 6 remaining blocks (nos. 5, 9, 11, 12, 21; see Fig. 1) had less vegetation and/or more buildings (including the first building more than 3 stories high, the Richmond County Judicial Center in Block 9 where the greatest vegetative loss occurred). Most loss of vegetation was removal of solitary trees and shrubs and hedgerows, usually for expansion of parking lots. The sixth block (no. 16) contained slightly more vegetation in the 3 later years than in 1994.

Species Turnover

Species turnover in 1994 compared to the 3 later years was a net loss of 7 native species (loss of 9, gain of 2). Territorial pairs of Common Grackles were absent from the study area in 2012 and 2016–2017; I found 1 old nest (from 2011) in early April 2012 at the former semi-colony in Block 25. Territorial pairs of American Robin were present in 2012 and 2016 but absent in 2017 (1 male sang on territory on 2 May, but that bird did not remain). Seven species present as single territorial pairs in 1994 were absent during the 3 later years, including 3 cavity nesting species (*Melanerpes carolinus* [L.] [Red-bellied Woodpecker], *Myiarchus crinitus* [L.] [Great Crested Flycatcher], *Sitta pusilla* Latham [Brown-headed Nuthatch]) and 4 open-cup nesting passerines (*Lanius ludovicianus* L. [Loggerhead Shrike], Blue Jay, *Icterus spurius* [L.] [Orchard Oriole], *Passerina caerulea* [L.] [Blue Grosbeak]).

Two new native passerines (*Stelgidopteryx serripennis* [Audubon] [Northern Rough-winged Swallow], *Spizella passerina* [Bechstein] [Chipping Sparrow]) nested within the study area during the later years. Chipping Sparrows were present during all 3 years (3.0, 3.5, and 1.0 territorial pairs, respectively), and I discovered 2 nests in *Quercus phellos* L. (Willow Oak) and *Pinus taeda* L. (Loblolly Pine). One pair of Northern Rough-winged Swallows nested in a decommissioned long trailer de-hitched from a cab (Block 1) in 2016 and 2017; in 2017, the pair abandoned the site in late April when the trailer was re-commissioned and moved.

Two species (Chimney Swift, *Charadrius vociferus* L. [Killdeer]) that nested as single pairs in 1994 also nested during the 3 later years. Three territorial pairs of Chimney Swifts nested in 3 chimneys in 3 blocks in all 3 years. Killdeers, which had nested on rooftops in downtown Rockingham since at least 1979, nested on the ground in 2017 (Block 11; adult incubating 4 eggs on 15 May, though the nest failed shortly thereafter). Finally, ~2.0 territorial pairs of Feral Pigeons were present in the later years in 2 blocks. *Accipiter cooperii* (Bonaparte) (Cooper's Hawk) preyed upon Feral Pigeons during the breeding season of 2011, including pigeons that nested inside the Everett-McNair Store (Block 7; J.R. Massey, Jr., Assistant City Manager, City of Rockingham, NC, pers. comm.). I observed a Cooper's Hawk preying on pigeons at a former hardware store (Block 1) during April–May 2017.

Discussion

This study has extended the usefulness of BBCs (Engstrom and James 1984) by coupling documentation of breeding territories by the spot-mapping method with the number of nest records in urban blocks as part of the Rockingham BBC. Town blocks with the greatest areas of buildings and the highest vegetation indices, respectively, were positively associated with species richness and the number of nest records of species categorized as urban invaders (Chace and Walsh 2006, Marzluff 2001) and suburban adapters (Beninde et al. 2015). The probable underestimation of the distribution (based on the number of nest records) of the Carolina Wren was not a critical shortcoming. Regardless, biotic homogenization of avian species richness, composition, and breeding densities within the central business district of Rockingham, North Carolina, is typical of the loss of biodiversity in most larger urban landscapes worldwide (Marzluff 2001, Marzluff et al. 2001).

Urban Invaders

The most abundant birds on the Rockingham BBC in 1994 in blocks dominated by buildings were 2 exotic resident cavity-nesting species (European Starling, House Sparrow). This pattern is expected in central business districts of cities and towns, including those in eastern North America (Aronson et al. 2014, Beninde et al. 2015, Chace and Walsh 2006, Clucas and Marzluff 2015, Kelcey and Rheinwald 2005, Marzluff 2001). Nonetheless, the number of blocks occupied by these 2 urban invaders at buildings was truncated at 12 blocks. Building condition, despite some vacancies, evidently set an upper limit to the number of blocks European Starlings and House Sparrows could occupy. Variation in building condition among blocks of different sizes is probably responsible for the lack of significant associations between building area and species richness or the number of nest records. Building condition in some blocks is still poor (e.g., Block 19, with a high number of nest records), but construction of relatively new buildings (e.g., Block 8, with a low number of nest records) and renovation and restoration efforts for over 20 years has slowly improved building condition in downtown Rockingham (e.g., the Everett-McNair Store [now Arts Richmond], formerly badly neglected, has been completely sealed). These renovation and restoration efforts at buildings, assisted by Cooper's Hawk predation, have been largely responsible for the decrease from a moderate to sparse distribution of another urban invader in Rockingham, the Feral Pigeon.

Recent data, other than imprecise general numbers, are lacking for European Starlings and House Sparrows in Rockingham, but in many areas of eastern North America since the bulk of urban and suburban BBCs were conducted in the 1970s and 1980s, urban populations of House Sparrows have steadily declined (Berigan et al. 2020, Sauer et al. 2017). This decline includes populations in the Piedmont of North Carolina (Hendrickson and Ferebee 1994, Westphal 2006). In Sackville, New Brunswick, this formerly abundant species (Erskine 1980, 1982) is now extirpated (Erskine 2006; A.J. Erskine, retired Canadian Wildlife Service employee, Sackville, New Brunswick, pers. comm.), and in Gainesville, Florida, the population has collapsed in suburban areas and sharply declined in urban areas, where House Sparrows remain most numerous in the central business district (Burnett and Moulton 2015).

Urban invaders include House Finch populations in eastern North America (Badyaev et al. 2012). This species' explosive population growth, including in urban areas such as the Piedmont of North Carolina (Hendrickson and Ferebee 1994, Westphal 2006), was interrupted by one of the worst epizootics in history—an outbreak of mycoplasmal conjunctivitis. The disease most likely did not reach Rockingham until between November 1994 and November 1995 (see Fig. 8 in Dhondt et al. 1998), probably arriving during the latter half of 1995 (Hochachka and Dhondt 2000). External symptoms of severe conjunctivitis (swollen, crusty, or closed eyes) were not observed in Rockingham during the breeding season of 1994 (D.B. McNair, pers. obs.). Thus, this study was conducted when a healthy House Finch breeding population was near or at its peak in downtown Rockingham in 1994, before its own pandemic began.

The resident House Finch occupied a unique position on the Rockingham BBC because breeding pairs used buildings and vegetation as nest-sites in almost equal proportions (cf., Badyaev et al. 2012), yet its number of nest records was only weakly associated with the area of either buildings or vegetation, especially the latter. This urban invader built its open-cup nests on, not within buildings, where its distribution was nonetheless restricted to 12 blocks, the same number of blocks as European Starlings and House Sparrows, but the House Finch was only ~45–50% as numerous as those 2 species. However, House Finches expanded their distribution within blocks and to additional blocks when they used vegetation as nest sites. Thus, the House Finch was the most widely distributed avian species that habitually used buildings on the Rockingham BBC plot, just ~11 years after House Finches probably first began breeding there ~1982–1983 (LeGrand 1982; LeGrand 1983a,b; LeGrand 1984). House Finches may compete with House Sparrows (Cooper et al. 2007, McClure et al. 2011), so an assessment of the current status of both urban invaders is urgently needed to measure changes in their presence or absence and use of buildings and vegetation as nest-sites within the 25-block area of downtown Rockingham since 1994.

Species Turnover

Biotic homogenization in downtown Rockingham worsened between 1994 and the later period (2012, 2016–2017) from loss of 2 of the 3 most abundant native open-cup species and a sharp reduction in the number of scarce native species, all of which are categorized as suburban adapters. The most unexpected result of this study was the loss of breeding Common Grackles in the 3 later years and the loss, in 2017, of American Robins. Both species were also absent in 2018 and 2019 (D.B. McNair, unpubl. data). These 2 species formerly bred at greater heights in vegetation compared to other avian species within the study area (D.B. McNair, unpubl. data). Almost all of the taller solitary trees, tree rows (including the former semi-colony site for Common Grackles), most hedges that contain some trees, and woodlots are still present. Maturation of habitat that has occurred during the 18–23 year gap between 1994 and the 3 later years would have favored, rather than discouraged, nesting by these 2 species. Furthermore, extensive lawns, a favorable habitat component for American Robins, also remain in some blocks. The loss of these 2 omnivores from the central business district, without replacement by any other abundant native species, has sharply reduced species richness and abundance on the Rockingham BBC plot.

Breeding Common Grackles are still common in North Carolina (Sauer et al. 2017, Westphal 2009). However, their disappearance from downtown Rockingham is consistent with a significant long-term decline in the Carolinas since the mid-1960s, which has accelerated since 2005 (Sauer et al. 2017). This sharp decline includes urban areas of the Piedmont of North Carolina (Westphal 2009). American Robins first expanded their breeding range to the Piedmont and Coastal Plain of North Carolina in the 1940s–1950s (Vanderhoff et al. 2016). American Robins are currently fairly common to common in the Piedmont and southeastern Coastal Plain (including North Carolina), where they are grouped as an urban breeder (Sauer et al. 2017). For example, the closest Bird Breeding Survey (BBS) route to Rockingham, at Hamlet, has averaged 11 American Robins/year since 1995 (range 5–24 birds; Sauer et al. 2017). Robins had a non-significant increase in North Carolina on BBS routes from 1966 to 2015 but decreased by 16% from 2005–2015 (Sauer et al. 2017). No other national or regional sources have detected a recent decline of breeding American Robins in southeastern North America. This local study reaffirms the long-term decline of breeding Common Grackles in North Carolina and also documents the collapse of the American Robin breeding population in downtown Rockingham, which warrants further investigation.

Seven native species that nested as single pairs in 1994 no longer bred in downtown Rockingham in the 3 later years. The 3 cavity species (Red-bellied Woodpecker, Great Crested Flycatcher, Brown-headed Nuthatch) visited the study area, but the removal of scarce snags and loss of nest boxes prevented nesting. Habitat remained substantially unchanged for the 4 open-cup species (Loggerhead Shrike, Blue Jay [which did visit], Blue Grosbeak, Orchard Oriole), but they did not breed. Less effort in the 3 later years may have failed to document a scarce species (but see McNair 2019), but species turnover of scarce species was substantial despite a rich source of potential immigrants in the immediate vicinity, including Northern Rough-winged Swallows and Chipping Sparrows (Appendix 1), which subsequently nested within the Rockingham BBC plot. Absent significant habitat changes, loss or gain of species that have only occurred as single pairs suggests the central business district of Rockingham represents sub-optimal habitat. Suburban adapters in the central business district of Rockingham probably still dominate, but the loss of American Robins and Common Grackles, which was not caused by vegetative changes, accompanied by the net loss of scarce native species would reduce suburban adapters' dominance vis-à-vis exotic urban invaders. Warren et al. (2019) recently documented a loss of bird species, including suburban adapters, in residential areas of metropoiitan Phoenix, Arizona, that was also not caused by major vegetative changes. They attributed the loss to an extinction debt, but the loss of suburban adapters in the old town of Rockingham, where urbanization pressure is low, is unlikely to be from an extinction debt.

Future Prospects

Disregarding standard maintenance practices by municipal and private authorities in the central business district of Rockingham, the general pattern of benign neglect of vegetative habitat over the last 20–25 years, except for elimination of isolated snags, has been favorable for birds in the oldest historical section of this town sitting on top of Cole's Hill. Favorable urban typology (Palomino and Carrascal 2006) has allowed Rockingham to live up to its namesake as a bird sanctuary, despite reduced species richness and bird densities, which are typical of built-up downtown areas (Cam et al. 2000, Marzluff 2001, Palomino and Carrascal 2006). Snep et al. (2016) proposed recommendations for habitat enhancement and other measures that would improve avian biodiversity in urban landscapes across North America within the context of socio-economic drivers but did not specify any economic incentives. By North American standards, Rockingham is no longer a wealthy town and generally lacks an economic impetus to cajole private landowners to improve habitat on commercial properties beyond minimal standards (City of Rockingham 2020). Thus, the many recommendations of Snep et al. (2016) are not useful for Rockingham because economic incentives are lacking.

The town of Rockingham (and Richmond County) also lacks a local cadre of dedicated field ornithologists to conduct BBCs using the spot-mapping method, unlike Winston-Salem, North Carolina (Thorington and Brand 2014), a large city. Unlike that study by Thorington and Brand (2014), other recent studies on urban and suburban birds in southeastern North America have been conducted by academic biologists using multiple sites and multi-scaled approaches requiring advanced statistical methods (e.g., at Raleigh and Cary, North Carolina [Mason et al. 2007]; Gainesville, Florida [Stracey and Robinson 2012]). Without professional involvement and greater demand, the defenestration of traditional BBC studies conducted by amateurs is likely to continue unless amateurs couple local ownership of traditional single-site studies with a long-term approach (e.g., as in Fairfax County, Virginia; Aldrich and Coffin 1980). Local ownership in Rockingham is lacking, although a local concentration of field ornithologists is present ~50 km away in prosperous Moore County, North Carolina. As North Carolina's population continues to rapidly grow (US Census Bureau 2020), especially in the Piedmont, "local" ownership of single sites will probably require recruitment of individuals from neighboring communities (McNair 2020). A repeat census of the Rockingham BBC plot, including nest searches, to advance our understanding of the patterns and processes of biotic homogenization of towns would be highly desirable. Regardless, future BBCs at most locations that, like Rockingham, are located in comparatively poor rural areas of southeastern North America will be difficult to resuscitate without economic incentives.

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Appendix 1. List of 50 avian species that visited the Rockingham, North Carolina, breeding bird census plot from 27 March to 30 July 1994 or nested within 0.4 km outside of its boundary.

Scientific name (Common name)	Visitor (V)	Nested (N) nearby
Aix sponsa (L.) (Wood Duck)	V	N
Coccyzus americanus (L.) (Yellow-billed Cuckoo)		N
Chordeiles minor (J.R. Forster) (Common Nighthawk)	V	
Archilochus colubris (L.) (Ruby-throated Hummingbird)		N
Butorides virescens (L.) (Green Heron)		N
Cathartes aura (L.) (Turkey Vulture)	V	
Accipiter striatus Vieillot (Sharp-shinned Hawk)	V	
Ictinia mississippiensis (A. Wilson) (Mississippi Kite)	V	
Buteo lineatus (Gmelin) (Red-shouldered Hawk)	V	N
Buteo platypterus (Vieillot) (Broad-winged Hawk)	V	N
Buteo jamaicensis (Gmelin) (Red-tailed Hawk)	V	N
Megascops asio (L.) (Eastern Screech-Owl)		N
Strix varia Barton (Barred Owl)	V	N
Megaceryle alcyon (L.) (Belted Kingfisher)	V	N
Dryobates pubescens (L.) (Downy Woodpecker)	V	N
Colaptes auratus (L.) (Northern Flicker)	V	N
Dryocopus pileatus (L.) (Pileated Woodpecker)		N
Tyrannus tyrannus (L.) (Eastern Kingbird)		N
Contopus virens (L.) (Eastern Wood-Pewee)		N
Empidonax virescens (Vieillot) (Acadian Flycatcher)		N
Sayornis phoebe (Latham) (Eastern Phoebe)		N
Vireo griseus (Boddaert) (White-eyed Vireo)		N
Vireo flavifrons Vieillot (Yellow-throated Vireo)		N
Vireo olivaceus (L.) (Red-eyed Vireo)		N
Corvus ossifragus (A. Wilson) (Fish Crow)	V	N
Stelgidopteryx serripennis (Audubon) (Northern Rough-winged Swallow)	V	N
Progne subis (L.) (Purple Martin)	V	N

Apprendix 1. Continued.

Scientific name (Common name)	Visitor (V)	Nested (N) nearby
Hirundo rustica L. (Barn Swallow)	V	N
Poecile carolinensis (Audubon) (Carolina Chickadee)		N
Baeolophus bicolor (L.) (Tufted Titmouse)	V	N
Polioptila caerulea (L.) (Blue-gray Gnatcatcher)		N
Sialia sialis (L.) (Eastern Bluebird)	V	N
Hylocichla mustelina (Gmelin) (Wood Thrush)		N
Bombycilla cedrorum Vieillot (Cedar Waxwing)	V	
Spinus tristis (L.) (American Goldfinch)	V	N
Spizella passerina (Bechstein) (Chipping Sparrow)	V	N
Zonotrichia albicollis (J.F. Gmelin) (White-throated Sparrow)	V	
Pipilo erythrophthalmus (L.) (Eastern Towhee)		N
Agelaius phoeniceus (L.) (Red-winged Blackbird)		N
Molothrus ater (Boddaert) (Brown-headed Cowbird)	V	N
Geothlypis trichas (L.) (Common Yellowthroat)	V	N
Setophaga ruticilla (L.) (American Redstart)	V	N
Setophaga americana (L.) (Northern Parula)		N
Setophaga petechia (L.) (Yellow Warbler)	V	
Setophaga striata (J.R. Forster) (Blackpoll Warbler)	V	
Setophaga pinus (L.) (Pine Warbler)		N
Setophaga coronata (L.) (Yellow-rumped Warbler)	V	
Setophaga dominica (L.) (Yellow-throated Warbler)	V	N
Piranga rubra (L.) (Summer Tanager)		N
Passerina cyanea (L.) (Indigo Bunting)	V	N
TOTAL SPECIES	30	41